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NOCTURNAL FORAGING AND HABITAT USE BY MALE BURROWING OWLS IN A HEAVILY-CULTIVATED REGION OF SOUTHERN SASKATCHEWAN

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Abstract.—Foraging habitat use of male Burrowing Owls (*Athene cunicularia*) was examined during the breeding season in a heavily-cultivated region of southern Saskatchewan. Four male Burrowing Owls were radio-tracked in June and July of 1997. The mean 95% Minimum Convex Polygon home range was 33.5 ha (range = 7.9–46.7 ha), and the 95% adaptive kernel home-range mean was 49.8 ha (range = 13.7–79.3 ha). Individual Chi-square analyses, of observed versus expected habitat use, revealed significant habitat selection in three of four owls. Crops and fallow were significantly avoided by two owls and one owl, respectively, and two owls significantly preferred pasture. Small-mammal abundance was highest in crops and right-of-way habitats and generally lowest in pastures, a pattern that was consistent among years, though small mammal abundance was higher overall in 1997 than in 1992 or 1993. Further study is needed to fully characterize nocturnal habitat requirements for Burrowing Owls, particularly if Canadian Species at Risk legislation calls for the protection of critical foraging habitat.

Key Words: *Burrowing Owl*; Athene cunicularia; *nocturnal foraging*; habitat use; *home range*; *small mammals*; *telemetry*; *Saskatchewan.*

Forrajeo nocturno y uso de hábitat por un macho de Búho Cavador en una región altamente cultivada del sur de Saskatchewan

Resumen.—El uso del hábitat de forrajeo del macho de Búho Cavador (*Athene cunicularia*) fue examinado durante la estación reproductiva en una región altamente cultivada del sur de Saskatchewan. Cuatro búhos cavadores machos fueron rastreados con radio en junio y julio de 1997. La media 95% del rango de acción del polígono mínimo convexo fue 33.5 ha (rango = 7.9–46.7 ha), y el 95% de la media del rango de acción ajustable Kernel fue 49.8 ha (rango = 13.7–79.3 ha). El análisis individual Chi-cuadrado, del uso de hábitat observado versus el esperado, reveló una selección significativa de hábitat en tres de cuatro búhos. Los cultivos y el barbecho fueron evitados significativamente por dos y un búho, respectivamente, y 2 búhos prefirieron pasturas significativamente. La abundancia de pequeños mamíferos fue mas alta en los cultivos y hábitats de "derecho de paso" y generalmente mas bajo en pastos, un patrón que fue consistente entre años, aunque la abundancia de pequeños mamíferos fue mas alta en conjunto en 1997 que en 1992 o 1993. Son necesarios mayores estudios para caracterizar totalmente los requerimientos de hábitat nocturno para los Búhos Cavadores, particularmente si la legislación de las Especies Canadienses en Peligro clama por la protección del hábitat critico de forrajeo.

[Traducción de Victor Vanegas y César Márquez]

The Burrowing Owl (*Athene cunicularia*) is listed as an Endangered Species in Canada (Wellicome and Haug 1995) and is considered a Bird of Conservation Concern in the United States (Holroyd et al. 2001). Potential causes for the decline of this species in Canada include habitat loss and fragmentation (Wellicome and Haug 1995); pesticide use (James et al. 1990); mortality during migration, on wintering grounds (Haug et al. 1993), and during the breeding season (Clayton and Schmutz 1997); and reduced productivity (Hjertaas et al. 1995).

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Recent work in Saskatchewan (Wellicome et al. 1997, Wellicome 2000) indicates food limits productivity, leading to questions about foraging habitat use and associated prey abundance. Nest-site characteristics have been described for Burrowing Owls (MacCracken et al. 1985, Green and Anthony 1989); however, little is known about their home range and nocturnal habitat use (but see Haug and Oliphant 1990). A better understanding of nocturnal foraging habitat requirements will be imperative for Burrowing Owls if proposed Species at Risk legislation in Canada requires identification and conservation of "critical habitats."

Saskatchewan Environment and Resource Management initiated this study in order to address the above gaps in our knowledge. This study focuses on the use of nocturnal habitat by male owls during the brood-rearing stage. The study focuses on this period of nesting for the following reasons: 1) food supply at this stage is more limiting than during egg laying (Wellicome 1997, 2000); 2) nocturnal hunting is for small mammals, which comprise the majority of prey items (Schmutz et al. 1991, Plumpton and Lutz 1993, Wellicome 2000); and 3) the male owl is the main provider of food during this stage (Haug et al. 1993).

Study Area and Methods

The study area is in the Moist Mixed-Grasslands Ecoregion of southern Saskatchewan, south of the cities of Moose Jaw (50°22'N, 105°33'W) and Regina (50°27'N, 104°39'W) and west of the town of Weyburn (49°40'N, 103°52'W). Extensive agricultural lands, used mainly for the production of cereal crops, has left a heavily-fragmented environment. Widely-dispersed, small cattle or horse pastures constitute the remaining nesting sites for Burrowing Owls in the area. These nesting pastures are situated in a landscape dominated by seeded crop or fallow fields and hay fields. Riparian areas are infrequent and consist mainly of ephemeral streams or low-lying regions within croplands or pastures with some low-lying sites being used as hay fields.

Owl Trapping. The capture of male Burrowing Owls was initiated in late-May and early-June prior to hatching. Because of the paucity of available nesting pastures within the study area, most owls tended to nest in close proximity. Only one owl from any one pasture was used for this study, with a 3-km minimum separation between nests. We selected only breeding male owls for trapping and attempted to ensure equal distribution throughout the study area. Owls were trapped by placing noose carpets around the nest burrow entrance and nearby roost burrows (Bloom 1987). Noose carpets were baited with dead laboratory mice. To prevent accidental capture of the female, the nest burrow was temporarily plugged while the female was underground inside the burrow. Male owls usually returned to the nest burrow on their own; however, if the owl had not returned after 20–30 min, we would flush the owl from its roosting spot in the direction of the carpeted nest or roost burrows. Owls were generally caught within 1–2 hr, but some owls required several attempts before being caught.

Each captured owl was weighed and banded with a U S Geological Survey aluminum band and a unique combination of color bands. Necklace-style radio transmitters (<6.0 g; Merlin Systems Inc., Boise, Idaho) were placed on all captured owls. Because each owl weighed at least 140 g, the weight load of each transmitter was always ≤4%. All nests were monitored continuously throughout the season to ensure they were still occupied.

Telemetry. Owls were followed from sunset (2100 H) to sunrise (0500 H) between 20 June–21 July 1997. All owls were tracked for each of the 1-hr blocks at least once during the study. Owls were located using 3-element hand-held antennas and Model SRX 400 receivers (Lotek Engineering Inc., Newmarket, Ontario). Simultaneous bearings were taken on each owl at 10-min intervals for 1 hr by two researchers in constant radio contact. Telemetry stations were situated at road intersections, field borders, or other locations that could be easily located on aerial photos. In most cases, distance from observers to the owl was ≤750 m, with a maximum transmitter range estimated to be about 1.5 km. Three to four owls were followed each night, and no owl was monitored twice in one evening. Researchers searched the vicinity of a nest for the owl until it was located, ensuring complete coverage of the area used by the owl. Owls were not followed during high winds or rain.

Small Mammal Sampling. Relative abundance of small mammals was estimated in five discrete habitat types found within the study area in 1992, 1993, and 1997. The five habitats sampled were crop, fallow, pasture, hay, and right-of-way (ROW). Crop consisted mainly of barley or wheat fields and, less commonly, specialty crops such as field peas. Fallow fields were areas tilled on a regular basis (at least once prior to sampling) or had standing stubble present. Pastures were usually heavily grazed by cattle or horses and had either native or tame vegetation ROW were roadside ditches that were adjacent to any of the other habitat types, and were usually mowed once during the growing season. Hay fields were planted to a forb/grass mixture. Both ROW and hay were sampled prior to mowing or haying activities.

Transects of 10 Museum Special snap-traps, baited with peanut butter, were placed in each habitat type. Each transect was >25 m from any edges with traps spaced at 10-m intervals (Davis 1990). ROW habitat is restricted in width (10–15 m), so each trapline was placed in the center of the ROW and ran parallel to the road. Traps were pre-baited for 1 d and then set for three consecutive days

Trapping in all years took place within the same study area, but not in the same fields; however, all five habitats were trapped within each year. The sampling sites were distributed evenly throughout the study area each year, but traps were not set close to known Burrowing Owl foraging sites, avoiding any possible influences on owl foraging behavior.

Statistical Analysis. For the purposes of this study, 'home range' will refer to the area used by male owls from approximately the time that their chicks hatched to about the time that those chicks fledged. To reduce error, only those locations obtained from telemetry bearings of ≥40° and ≤140° were included. The cluster sampling strategy, adopted primarily for logistical reasons, can lead to autocorrelation of data points. To reduce the interdependence of data, we used locations separated by at least 20 min, which is ample time for the owls to traverse their home range.

Two methods were used to determine home-range size for the owls. The 95% minimum convex polygon (MCP) (White and Garrott 1990) method was used to facilitate comparison with Haug and Oliphant (1990). The 95% adaptive kernel method, an improved home-range estimator that takes into consideration the density of location estimates (Worton 1989), was also used. Home-range analyses were performed using the program Tracker (Version 1.1; Camponotus AB, Sweden) with default settings.

Error polygons were created for each location within program Tracker, following the method of Lenth (1981). Tracker uses a default bearing standard deviation of 8.0° to estimate error polygons. This value is lower than our bearing standard deviation assessed in the field (5.6°) but we accepted the higher value because of a low sample size (N = 12) in our error estimation. Utilized habitats were determined by overlaying this error ellipse on 1: 20 000 scale aerial photos of the study area. Proportional coverage of all habitats within the error ellipse was visually estimated, to the nearest 5%, accounting for 100% of the area.

Availability of habitats was determined by overlaying the home-range polygon for each owl on 1:20 000 scale aerial photos. A fine-scale dot-grid was then placed on top. To determine relative proportions of each habitat type, the number of dots were counted within each habitat type and then divided by the total number of dots for the entire home range. The expected distribution of telemetry locations was determined by multiplying the proportion of each available habitat by the total number of locations for each owl. Only locations >50 m from the nest were assumed to be foraging sites (Haug and Oliphant 1990), and this 50-m buffer was not included as available habitat. Six habitat types were defined using this method: pasture, crop, fallow, riparian, ROW, and farmyard. Pasture, crop, fallow, and ROW habitats follow the description given above for small mammal sampling. Riparian habitats consisted of small streams with associated vegetation running through pastures or crop/fallow fields. Farmyards represent all buildings, lawns and shelterbelts associated with the primary residence of the landowner.

The null hypothesis, that Burrowing Owls use habitats proportional to availability, was tested using a Chi-square analysis of observed versus expected habitat use locations (Neu et al. 1974, Zar 1996). To determine if a habitat was significantly preferred or avoided, simultaneous confidence intervals were calculated using the Bonferroni adjustment (Neu et al. 1974, Byers et al. 1984). Each owl was treated individually in the analysis because habitat-use distributions were heterogeneous (χ^2 = 12.92, df = 5, P = 0.03, therefore reject H_O: that habitat use was homogenous; Zar 1996:467).

Relative abundance of small mammals is presented as the number of captures per 100 trap nights corrected for closed traps (Nelson and Clark 1973). All species caught were pooled into the 'small mammal' category. Trapping effort in 1997 was approximately half of that in 1992–1993 (46 total transects vs. 110 and 95, respectively), but we feel this is sufficient for the level of comparison presented in this paper.

Table 1. Breeding season home-range size of four male Burrowing Owls (BUOW) near Regina, Saskatchewan, in 1997. MCP = Minimum Convex Polygon.

	95% MCP (ha)	95% ADAPTIVE KERNEL (ha)	N
BUOW No. 1	43.3	56.1	54
BUOW No. 2	7.9	13.7	66
BUOW No. 3	46.7	79.3	58
BUOW No. 4	36.2	50.3	56
Mean (SE)	33.5 (8.8)	49.8 (13.6)	58.5

RESULTS

Transmitters were attached to 11 male owls, but one owl was depredated 8–10 d later by an avian predator. The transmitters on six other owls failed, primarily because owls damaged or removed antennae. These failures occurred 7–10 d after transmitter attachment. Data collected on these owls were insufficient for inclusion in this study due to limited data points (<15) and inadequate temporal coverage. Consequently, adequate data were available for only four owls. Mean MCP home-range size for the four owls is 33.5 ha (SE = 8.8), and mean kernel home range is 49.8 ha (SE = 13.6; Table 1).

Habitat-use analysis shows that three of the owls used habitats in a significantly different manner than expected under the hypothesis of proportional use (Table 2). Owl No. 1 was the exception, showing no significant departure from expected habitat use. Two of the remaining owls avoided crop at varying levels of significance, and only Owl No. 3 significantly avoided fallow (Table 2). Two owls also showed a significant preference for pasture (Table 2).

In 1132 trap nights in 1997, four species of small mammals were caught. Deer mice (*Peromyscus maniculatus*) were most common, occurring in all sampled habitats. Meadow voles (*Microtus pennsylvanicus*) were second highest in abundance, but were only found in hay fields, ROW, and pastures. A few house mice (*Mus musculus*) and an unknown species of shrew (*Sorex* spp.) were caught, but only in ROW habitat. Compared with data from 1992–93, small mammals as a group in 1997 had a higher abundance in all habitat types, except pastures (Fig. 1).

DISCUSSION

It is difficult to extrapolate habitat associations from four Burrowing Owls to the entire owl population. Patterns seen in this study may be indicative of Burrowing Owl behavior on a larger scale, but broad-scale conclusions or inferences from this study must be kept in check. This is especially important when one considers the uniqueness of 1997 in terms of prey abundance (Fig. 1). There are no long-term small mammal studies for this area, but anecdotal evidence does exist to support that 1997 was a unique year. Local landowners indicated they had not seen such abundance of small mammals since the late-1960s. Additionally, sightings of several species of raptor increased substantially from previous years, most notably the Short-eared Owl (*Asio flammeus*; Poulin et al. 2001). This species is well known to be irruptive and is thought to track small mammal populations, in particular *Microtus* species (Holt and Leasure 1993). Meadow voles were a great deal higher during the breeding season in 1997 than in previous years (Wellicome 2000, Poulin et al. 2001).

Abundant prey in 1997 may explain the relatively small home ranges of the four owls in this study. Haug (1985) recorded a mean home range of 241 ha (range = 14–481 ha) for six male owls near Saskatoon in 1982–83. The estimated 2-yr mean for small mammal abundance in the Saskatoon study area (data not recorded by habitat type) was 3.4 mice/100 trap nights (Haug 1985). This is substantially lower than the abundance of 22.7 mice/100 trap nights recorded in this study area in 1997 (all habitats combined).

In general, Burrowing Owls in this study avoided croplands and fallow, preferred pastures, and utilized other habitats in proportion to occurrence on the landscape. Avoidance of crops can be explained by the structure of the environment: crops tend to be tall (>0.5 m) and dense, limiting access to prey. Haug (1985) recorded similar results (although with a higher level of significance): owls avoided croplands and grazed pastures and preferred habitats with a grass/forb cover, including ROW, hay fields, and ungrazed pastures. The avoidance of cropland and higher use of pastures in this study indicates that prey abundance alone does not drive foraging-habitat selection in these owls, especially in a high-food year.

While this study experienced technical difficulties with respect to the transmitters, we hope this does not dissuade continued research on Burrow-

Table 2. Observed and expected habitat use and Bonferroni confidence intervals (CI) of four Burrowing Owls (BUOW) near Regina, Saskatchewan, in 1997. Asterisks show level of significance for the CI: * = 0.1, ** = 0.05, and *** = 0.01. Results from habitat-use analysis for BUOW No. 1: $\chi^2 = 7.03$, df = 5, $P = 0.22$; BUOW No 2: $\chi^2 = 11.66$, df = 3, $P < 0.01$; BUOW No. 3: $\chi^2 = 25.95$, df = 2, $P < 0.01$; BUOW No. 4: $\chi^2 = 11.81$, df = 5, $P = 0.04$. "n/a" indicates that habitat was not present in the individual's home range.

Habitat Type	Observed Proportion	Expected Proportion	Bonferroni Confidence Intervals
BUOW No. 1			
Crop	0.12	0.28	0.12 ≤ x ≤ 0.45
Fallow	0.52	0.40	0.23 ≤ x ≤ 0.58
Pasture	0.17	0.13	0.01 ≤ x ≤ 0.25
Riparian	0.08	0.07	0.00[a] ≤ x ≤ 0.10
ROW	0.01	0.04	0.00[a] ≤ x ≤ 0.16
Farmyard	0.04	0.09	0.00[a] ≤ x ≤ 0.19
BUOW No. 2			
Crop	0.21	0.37	0.21 ≤ x ≤ 0.52**
Fallow	0.42	0.33	0.17 ≤ x ≤ 0.48
Pasture	0.27	0.17	0.05 ≤ x ≤ 0.29
Riparian	n/a	n/a	—
ROW	0.10	0.14	0.03 ≤ x ≤ 0.26
Farmyard	n/a	n/a	—
BUOW No. 3			
Crop	0.13	0.28	0.14 ≤ x ≤ 0.43*
Fallow	0.19	0.35	0.20 ≤ x ≤ 0.50*
Pasture	0.68	0.36	0.16 ≤ x ≤ 0.56***
Riparian	n/a	n/a	—
ROW	n/a	n/a	—
Farmyard	n/a	n/a	—
BUOW No. 4			
Crop	0.14	0.25	0.10 ≤ x ≤ 0.41
Fallow	0.41	0.43	0.26 ≤ x ≤ 0.61
Pasture	0.33	0.19	0.05 ≤ x ≤ 0.33**
Riparian	0.08	0.05	0.00[a] ≤ x ≤ 0.13
ROW	0.01	0.02	0.00[a] ≤ x ≤ 0.08
Farmyard	0.02	0.05	0.00[a] ≤ x ≤ 0.13

[a] The true lower confidence limit was a negative number and was therefore adjusted to 0.00.

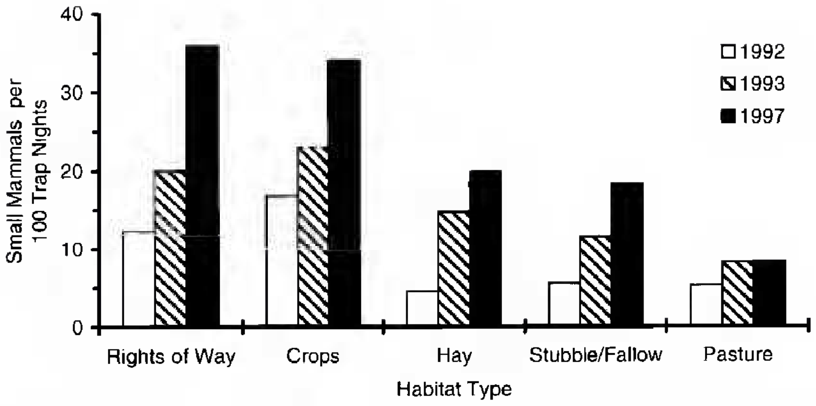

Figure 1. Small mammal abundances in the Burrowing Owl study area in 1992, 1993, and 1997. Trapping was conducted in June and July of each year. Four species were captured (listed in order of abundance): deer mouse, meadow vole, house mouse, and an unidentified shrew species.

ing Owl foraging ecology. The necklace-style design of the transmitters may have contributed to their destruction by the owls. Necklace transmitters are required to be loose-fitting to allow for food intake and pellet regurgitation. This loose fit leads to constant movement of the transmitter, possibly provoking the owls to attempt to remove them. Backpack-style transmitters may be an alternative as they are snug-fitting, but are more difficult to attach, requiring additional time to handle the birds. Continued exploration of transmitter design and attachment techniques is needed, including experiments on captive-raised Burrowing Owls if possible.

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LITERATURE CITED

BLOOM, P.H. 1987. Capturing and handling raptors. Pages 99–123 *in* B.A. Giron-Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird [EDS.], Raptor management techniques manual. Natl. Wildl. Fed., Washington, DC U.S.A.

BYERS, C.R., R.K. STIENHORST, AND R. KRAUSMAN. 1984. Clarification of a technique for analysis of utilization-availability data. *J. Wildl. Manage.* 54:1050–1053.

CLAYTON, K.M. AND J.K. SCHMUTZ. 1997. Burrowing Owl (*Speotyto cunicularia*) survival in prairie Canada. Pages 107–110 *in* J.R. Duncan, D.H. Johnson, and T.H. Nicholls [EDS.], Biology and conservation of owls of the northern hemisphere: 2nd international symposium. USDA Gen. Tech. Rep. NC-190, St. Paul, MN U.S.A.

DAVIS, D.E. 1990. CRC handbook of census methods for terrestrial vertebrates. CRC Press Inc., Boca Raton, FL U.S.A.

GREEN, G.A. AND R.G. ANTHONY. 1989. Nesting success and habitat relationships of Burrowing Owls in the Columbia Basin, Oregon. *Condor* 91:347–354.

HAUG, E.A. 1985. Observations on the breeding ecology of Burrowing Owls in Saskatchewan. M.S. thesis, Univ Saskatchewan, Saskatoon, SK Canada.

———, B.A. MILLSAP, AND M.S. MARTELL. 1993. Burrowing Owl (*Speotyto cunicularia*). *In* A. Poole and F. Gill [EDS.], The birds of North America, No. 61. The Academy of Natural Sciences, Philadelphia, PA and American Ornithologists' Union, Washington, DC U.S.A.

——— AND L.W. OLIPHANT. 1990. Movements, activity patterns, and habitat use of Burrowing Owls in Saskatchewan. *J. Wildl. Manage.* 54:27–35.

HJERTAAS, D.G., S. BRETCHEL, K. DE SMET, O. DYER, E.A HAUG, G.L. HOLROYD, P.C. JAMES, AND J.K. SCHMUTZ. 1995. National recovery plan for the Burrowing Owl Report No. 13. Recovery of Nationally Endangered Wildlife, Ottawa, ON Canada. http://www.cws-scf.ec gc.ca/es/Burrowing_Owl.html.

HOLROYD, G.L., R. RODRIGUEZ-ESTRELLA, AND S.R. SHEFFIELD. 2001. Conservation of the Burrowing Owl in western North America: issues, challenges, and recommendations. *J. Raptor Res.* 35:399–407.

HOLT, D.W. AND S.M. LEASURE. 1993. Short-eared Owl (*Asio flammeus*). *In* A. Poole and F. Gill [EDS.], The birds of North America, No. 61. The Academy of Natural Sciences, Philadelphia, PA and American Ornithologists' Union, Washington, DC U.S.A.

JAMES, P.C, G.A. FOX, AND T.J. ETHIER. 1990. Is the operational use of strychnine to control ground squirrels detrimental to Burrowing Owls? *J. Raptor Res.* 24:120–123.

LENTH, R.V. 1981. On finding the source of a signal. *Technometrics* 23:149–154.

MACCRACKEN, J.G., D.W. URESK, AND R.M. HANSEN. 1985 Vegetation and soils of Burrowing Owl nest sites in Conata Basin, South Dakota. *Condor* 87:152–154.

NELSON, L. AND F.W. CLARK. 1973. Correction for sprung traps in catch/effort calculations of trapping results *J. Mammal.* 54:295–298.

NEU, C.W., C.R. BYERS, AND J.M. PEEK. 1974. Technique for analysis of utilization-availability data. *J. Wildl. Manage.* 38:541–545.

PLUMPTON, D.L. AND R.S. LUTZ. 1993. Prey selection and food habits of Burrowing Owls in Colorado. *Great Basin Nat.* 53:299–304.

POULIN, R.G., T.I. WELLICOME, AND L.D. TODD. 2001. Synchronous and delayed numerical responses of a predatory bird community to a vole outbreak on the Canadian prairies. *J. Raptor Res.* 35:288–295.

SCHMUTZ, J.K., G. WOOD, AND D. WOOD. 1991. Spring and summer prey of Burrowing Owls in Alberta. *Blue Jay* 49:93–97.

WELLICOME, T.I. 1997. Reproductive performance of Burrowing Owls (*Speotyto cunicularia*): effects of supplemental food. Pages 68–73 *in* J.L. Lincer and K. Steenhof [EDS.], The Burrowing Owl, its biology and management including the proceedings of the first international Burrowing Owl symposium. J. Raptor Res. Report 9.

———. 2000. Effects of food on reproduction in Burrowing Owls (*Athene cunicularia*) during three stages of the breeding season. Ph.D. dissertation, Univ. Alberta, Edmonton, AB Canada.

——— AND E.A. HAUG. 1995. Second update of status report on the Burrowing Owl *Speotyto cunicularia* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON Canada.

———, G.L. HOLROYD, K. SCALISE, AND E.R. WILTSE 1997. The effects of predator exclusion and food supplementation on Burrowing Owl (*Speotyto cunicularia*) population change in Saskatchewan. Pages 487–497 *in* J.R. Duncan, D.H. Johnson, and T.H. Nicholls [EDS.], Biology and conservation of owls of the northern hemisphere: 2nd international symposium. USDA Gen. Tech. Rep. NC-190, St. Paul, MN U.S.A.

WHITE G.C. AND R.A. GARROTT. 1990. Analysis of wildlife radio-tracking data. Academic Press Inc., San Diego, CA U.S.A.

WORTON, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70:164–168.

ZAR, J.H. 1996. Biostatistical analysis, 3rd Ed. Prentice Hall, Upper Saddle River, NJ U.S.A.